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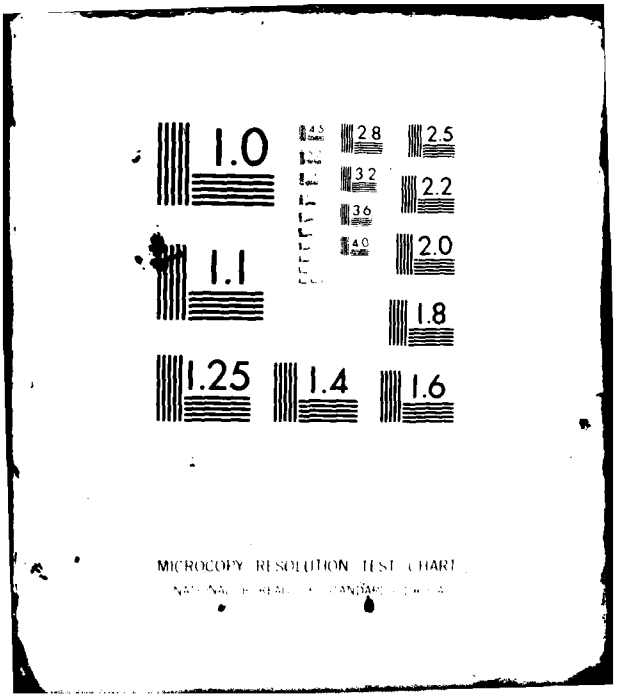
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NAVFAC DM-2.5
MAY 1980

STRUCTURAL ENGINEERING

TIMBER STRUCTURES

DESIGN MANUAL 2.5

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*
Basic criteria for the design of timber structural elements and timber structural systems are presented for use by experienced engineers. The contents cover general topics concerning design standards for bridge and building structures and details of design. A section on selection of species and grade of timber is included. Special considerations in the design of plywood elements and of built-up members, problems of wood preservation and termite control, fire retardant treatment, and climatic influences are discussed.

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FOREWORD

This design manual is one of a series developed from an evaluation of facilities in the shore establishment, from surveys of the availability of new materials and construction methods, and from selection of the best design practices of the Naval Facilities Engineering Command, other Government agencies, and the private sector. This manual uses to the maximum extent feasible, national professional society, association, and institute standards in accordance with NAVFACENGCOM policy. Deviations from these criteria should not be made without prior approval of NAVFACENGCOM Headquarters (Code 04).

Design cannot remain static any more than can the naval functions it serves or the technologies it uses. Accordingly, recommendations for improvement are encouraged from within the Navy and from the private sector and should be furnished to NAVFACENGCOM Headquarters, Code 04. As the design manuals are revised, they are being restructured. A chapter or a combination of chapters will be issued as a separate design manual for ready reference to specific criteria.

This publication is certified as an official publication of the Naval Facilities Engineering Command and has been reviewed and approved in accordance with SECNAVINST 5600.16.

D. G. Iselin

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Rear Admiral, CEC, U.S. Navy
Commander
Naval Facilities Engineering Command

STRUCTURAL ENGINEERING DESIGN MANUALS

New DM Number	Superseded Chapter in Basic DM	Subject
2.1	-	General Requirements
2.2	1	Loads
2.3	2	Steel Structures
2.4	3	Concrete Structures
2.5	4	Timber Structures
2.6	5, 6, 7, 8	Aluminum Structures Masonry Structures Composite Structures Other Structural Materials
2.7	-	Snow Loads (Tri-Service)

CONTENTS

TIMBER STRUCTURES

CONTENTS (continued)

TABLE

Section 1. SCOPE AND RELATED CRITERIA

1. SCOPE. This manual prescribes criteria for the design of structures, including temporary structures, which are fabricated of timber and related materials.

2. CANCELLATIONS. This manual, NAVFAC DM-2.5, Timber Structures, cancels and supersedes Chapter 4 of Structural Engineering, NAVFAC DM-2, of October 1970, and Changes 1 and 2.

3. RELATED CRITERIA. Certain criteria related to the design of timber structures appear in other chapters of this design manual and other manuals in the design manual series, as follows:

Subject	Source
General Requirements . . . . . Service Classifications and Other General Requirements	NAVFAC DM-2.1
Soil Mechanics, Foundations and Earth Structures . . . . . Foundations	NAVFAC DM-7
Fire Protection Engineering . . . . . Fire Protection	NAVFAC DM-8
Standard Specifications for Highway Bridges . . . . . Bridges	American Association of State Highway and Transportation Officials (AASHTO)
Manual for Railway Engineering . . . . . Bridges	American Railway Engineer Association (AREA)
National Design Specification for Wood Construction . . . . . Timber	National Forest Products Association
Timber Construction Manual . . . . . Timber	American Institute of Timber Construction
Plywood Design Specification . . . . . Timber	American Plywood Association
Design Specification for Light Metal Plate Connected Wood Trusses . . . . . Timber	TPI Publications

4. STANDARD SPECIFICATIONS. Throughout this manual, where design criteria are obtained from cited sources, those citations are termed "Standard Specifications."

Section 2. DESIGN STANDARDS

Part 1. CLASS A STRUCTURES

1. HIGHWAY BRIDGES. AASHTO Standard "Standard Specifications for Highway Bridges" shall apply.

2. RAILWAY BRIDGES. AREA Standard "Manual for Railway Engineering" shall apply.

3. OTHER. Unless special considerations exist, the AASHTO Standard "Standard Specifications for Highway Bridges" shall apply. Specifically, the AASHTO Standard may be followed in the design of structures supporting equipment moving on tracks (except where classified as Class B in DM-2.1, para. 5) if the provisions for distribution of concentrated loads are modified to reflect the effects of the tracks.

4. PLYWOOD MEMBERS. Allowable stresses shall be 90 percent of the values for Class B and Class C structures.

Part 2. CLASS B AND CLASS C STRUCTURES

1. LUMBER AND TIMBER, INCLUDING GLUE-LAMINATED MEMBERS. NFPA Standard, "National Design Specification for Wood Construction." Additional criteria and design applications are contained in AITC "Timber Construction Manual."

a. Sealers. Where feasible, minimize seasoning checks in the ends of timber pieces installed in an unseasoned condition by the use of end coating or sealers.

b. Connections. Connections shall be detailed to permit periodic tightening.

c. Hardware. Bolt holes for drift bolts shall be bored with a bit having a diameter 1/8 inch less than the bolt diameter.

2. PLYWOOD. APA Standard, "Plywood Design Specification," including the supplements listed in the appendix, and APA publications "Plywood Folded Plates" and "Plywood Diaphragm Construction" shall apply. For plywood treated with fire-retardant salts, reduce physical properties in APA standards by:

Modulus of Elasticity (E) - 10 percent
Modulus of Rupture (G) - 20 percent

3. LIGHT WOOD TRUSSES.

a. Light Metal Plate Connected Wood Trusses. Design in conformance with Sections 200 and 300 of TPI, "Design Specifications for Light Metal Plate Connected Wood Trusses."

b. Glued-Nailed Trussed Rafters. Design in accordance with the method and data described in the Purdue University Agricultural Experiment Station Research Bulletins No. 714, "Determination of Member Stresses in Wood Trusses with Rigid Joints," and No. 727, "The Design of Glued Joints for Wood Trusses and Frames."

Section 3. DETAILS OF DESIGN

Part 1. SELECTION OF SPECIES AND GRADE

1. GENERAL.

a. Stress Grade Lumber. Design values shall be in accordance with the species and grade selected from the NFPA Standard. Where preservative treatment is required, selection of species should consider ease and efficacy of treatment.

b. Nonstress Grade Lumber may be used for miscellaneous framing such as nailers, caps, bucks, grounds, sleepers, blocking, bridging, plates, and furrings. Such members shall be "Standard" grade or better.

c. Plywood. Plywood shall be of species groups 1, 2, or 3, as classified in the APA Standard.

d. Durability. See data in USDA "Wood Handbook."

2. NONDOMESTIC SPECIES OF TIMBER.

a. Properties. Many nondomestic species of timber are suitable for construction work. Some have very high strength and are more durable than softwoods. Resistance to attack by marine borers is claimed for some species, but performance data suggest that such resistance is not reliable. A partial listing of nondomestic timbers and their properties is contained in Table 1. Items of particular interest are:

(1) Pressure preservative treated Apitong (Dipterocarpus grandiflorus blanco) is highly suitable for wood piling and utility poles.

(2) The tropical woods Ipil (Intsia bijuga), Daog or Palomara (Calophyllum inophyllum), Ahgao (Premna obtusifolia), Fago (Ocbrosia oppositifolia), Yacal (Hopea, Sborea, and Isoptera species), Molave (Vitex parviflora Juss), and Chopag (Ocbrocarpos odoraturus) are satisfactory for most structural uses. Redwood shall be used structurally only in cooling towers.

TABLE 1
Properties of Nondomestic Species of Timber

Region	Name	Bending Strength	Hardness	Shock Resistance	Specific Gravity	Durability	Marine Borer Resistance	Availability
British Guiana	Greenheart	Very Strong	Very Hard	Good	0.93	Good	Fair	Abundant
French Guiana	Angelique	Strong	Strong	Hard	0.72	Good	Fair	Fair
Brazil	Piquia	Strong	Hard	Good	0.88	Good	Fair	?
British Guiana	Maristribaili	Very Strong	Very Hard	Good	1.09	Excellent	Excellent	?
South America	Acapu	Strong	Hard	Good	0.95	Good	Good	Fair
British Guiana	Black Kakeralli	Strong	Very Hard	Good	1.00	Excellent	Excellent	?
Western Pacific Region	Aroeng	Strong	Hard	Good	0.83	Good	Good	Fair
Western Pacific Region	Ipil	Very Strong	Very Hard	Good	0.78	Good	Good	Limited
Western Pacific Region	Kasi-Kasi	Fair	Hard	Good	0.61	Good	Very Good	Fair
Western Pacific Region	Dungon-late	Strong	Hard	Good	1.01	Good	Very Good	Fair
Western Pacific Region	Pagatpat	Strong	Hard	Good	1.03	Good	Good	Fair
Western Pacific Region	Bogoia	Strong	Hard	Good	1.14	Good	Very Good	Plentiful
Philippine Islands	Anubing	Fair	Moderate	Good	0.75	Good	Very Good	Fair
Philippine Islands	Alupag	Strong	Hard	Fair	0.97	Very Good	Good	Limited
Philippine Islands	Apitong	Strong	Hard	Good	0.80	Creosoting Recommended	Good	Plentiful
Philippine Islands	Bensalagin	Strong	Very Hard	Good	1.06	Good	Fair	Fair
Philippine Islands	Kalamansanasi	Strong	Very Hard	Good	0.93	Fair	Fair	Fair
Philippine Islands and New Guinea	Narig	Very Strong	Very Hard	Good	0.97	Good	Very Good	Fair
New Britain and New Guinea	Komo Kamarere	Strong	Hard	Good	0.83	Good	Fair	Fair
New Britain and Bismarck	Malasa	Strong	Hard	Good	0.97	Good	Good	Fair
New Britain and Moluccas	Zizanu	Good	Hard	Good	0.75	Good	Good	Plentiful
South Papua	Paper-bark	Strong	Very Hard	Fair		Good	Good	Abundant
South China Sea Region	Kiet-mouk	Strong	Hard	Good	0.97	Good	Fair	Fair
South China Sea Region	Doengon	Strong	Hard	Good	1.01	Good	Fair	Fair
South China Sea Region	Sehg Kang Wang	Strong	Very Hard	Good	1.04	Very Durable	Good	Fair
South China Sea Region	Bakau-belakup	Strong	Hard	Good	0.9[illegible]	Durable	Good	Plentiful

TABLE 1 (continued)
Properties of Nondomestic Species of Timber

Region	Name	Bending Strength	Hardness	Shock Resistance	Specific Gravity	Durability	Marine Borer Resistance	Availability
South China Sea Region	Baratlauk	Very Strong	Hard	Good	1.11	Very Durable	Good	Fair
South China Sea Region	Balam sundik	Strong	Hard	Good	0.77	Very Durable	Good	Fair
East Indies	Moluccan Ironwood	Strong	Very Hard	Good	0.77	Good	Fair	Fair
Thailand	Deng	Very Strong	Hard	Good	1.10	Good	Good	Plentiful
Thailand	Lumpaw Maca-mong	Very Strong	Hard	Good	0.77	Good	Good	Plentiful
Thailand	Kleng	Strong	Hard	Good	0.90	Good	Good	Fairly Plentiful
Thailand	Rang	Strong	Hard	Good	0.99	Good	Good	Plentiful
Thailand and Burma	Teng	Strong	Hard	Good	1.04	Good	Good	Plentiful
Malaya and Burma	Kojoe Batoe	Strong	Hard	Good	0.98	Durable	Good	Fair
Burma	Pyinkado	Strong	Hard	Good	0.95	Very Durable	Good	Abundant
Borneo	Lizerhout	Very Strong	Very Hard	Good	1.03	Very Durable	Good	Fair
Nepal	Sal	Strong	Very Hard	Good	0.90	Durable	Good	Fair
Nepal	Sandan	Strong	Hard	Good	0.89	Durable	Fair	Fair
Nepal	Dhaura	Strong	Hard	Good	0.92	Durable	Fair	Fair
East Pakistan	Chaplash	Fair	Fair	Good	0.65	Durable	Very Good	Fair
East Pakistan	Nageswar	Very Strong	Very Hard	Good	1.02	Very Durable	Good	Fair
West Africa	Ekki	Very Strong	Very Hard	Good	0.97	Very Durable	Very Good	Plentiful
West Africa	KoKrodua	Strong	Hard	Good	0.70	Very Durable	Good	Plentiful
Australia	Jarrah	Strong	Hard	Good	0.80	Very Durable	Good	Plentiful
Australia	Ironbark	Very Strong	Very Hard	Good	1.10	Very Durable	Good	Plentiful

(3) The following tropical woods, on Guam, should be used only when construction is to be of a temporary nature: Coconut (Cocs nucifera), Dugdug (Artocarpus sp.), Nunu (Ficus prolixa), Yoga (Elacocarpus joga), and Faya (Tristiropsis obtusangula).

(4) Specifications for Azobe (Ekki) are contained in Military Specification MIL-L-22626.

b. Allowable Stresses. Strength properties of individual species should be obtained from the potential supplier. Allowable stresses should be one-fourth to one-third of the ultimate strengths. The designer should regard characteristics as published by the supplier with caution and should insist on tests of random specimens to verify assumed strength characteristics.

Part 2. SPECIAL CONSIDERATIONS

1. MECHANICALLY LAMINATED MEMBERS. Allowable unit stresses for individual pieces used in mechanically laminated members shall comply with those established for sawn lumber. Adhesives used in combination with nails, spikes, bolts, lag bolts, or wood screws in mechanically laminated members shall not be considered as sharing the stress with the fasteners. Allowable loads in connectors shall conform to the provisions of the NFPA Standard. In vertically laminated beams where spikes are used, provide through bolts or bolts with connectors to prevent separation of the planks. Place two bolts at each end of the beam to hold the ends together. Transverse joints in the planks shall not be considered as transmitting any stress.

2. PLYWOOD MEMBERS.

a. Built-Up Plywood Girders. Observe the following precautions:

(1) Allowable shear stress between flanges and web shall not exceed 0.375 times allowable stress in horizontal shear.

(2) Web stiffeners shall be screwed or glued to webs and in contact with both flanges. The thickness shall be at least 6 times the thickness of the web; b/t shall not exceed 8; and minimum thickness shall be 3/8 inch. Stiffeners shall be as wide as the flange. Spacing shall be equal to or less than 2 times the clear distance between flanges.

(3) Provide wood blocks (bearing stiffeners) at points of concentrated load or bearing, or both.

(4) For deep girders, reduce the allowable stresses to account for the lack of lateral support of the center fibers as compared to the flange fibers.

b. Stressed-Skin Panels. In bending, tension, and compression consider only those plies where the grain is parallel to the span.

c. Exposure. Where exposed to weather or in humid locations (toilets and shower rooms are examples) use exterior grades of plywood.

3. GLUED, BUILT-UP (INCLUDING LAMINATED) MEMBERS. Design standards, procedures, and provisions for individual components (whether plywood or sawn lumber) shall conform to the requirements for such components as previously indicated, except as follows:

a. Transverse Joints. Transverse joints in the planks may be considered as transmitting stress if scarfed joints having a slope not steeper than 1:10 are used. Joints shall be spaced not less than 24 times the lamination thickness in areas of maximum stress. In lesser stressed areas, spacing may be reduced linearly in proportion to relative stress. Butt joints shall not be used for structural members.

b. Mechanical Fasteners. Mechanical fasteners shall not be used in conjunction with glued construction. The movements required to develop the mechanical fasteners are inconsistent with those permitted in glued joints.

c. Exposure. Glue-laminated members may be used in exterior exposure and under conditions of exposure to moisture and biologically destructive agents, as they show good resistance to degradation by these agents.

4. WOOD PRESERVATION. The use of treated timbers is recommended under the following conditions and subject to the following requirements.

a. Preservative Treatment. Preservative treatment shall be in accordance with the AWPI "Book of Standards." Note the following:

(1) Creosote and creosote solutions are not recommended where color, odor, or exudation of the preservative may be undesirable. Waterborne preservatives or oilborne preservatives in volatile solvents should be used.

(2) Where cleanliness and paintability are required, preservatives should be of the waterborne type or the oilborne type in volatile solvents.

b. Structural Framing. Pressure preservative treatment for timber should be used under the following conditions of exposure:

(1) All wood in contact with ground or water.

(2) Wood in contact with masonry or metal, where conduction or condensation creates problems.

(3) Roof structures (framing and sheathing) installed over enclosed swimming pools, or in building structures where high humidities prevail.

(4) Areas in or near shower rooms, galleys, sculleries, laundry rooms, and cold-storage rooms.

(5) Areas of basementless buildings in close proximity to the soil, where moisture and termites can attack the structural elements.

(6) All lumber within 18 inches of the ground in slab-on-ground or crawlspace houses (basementless).

(7) All structural wood members in regions where dry-wood termites prevail.

(8) On waterfront structures, as specified in NAVFAC DM-25.

c. Frame Before Treatment. To the extent practicable, treated wood structures should be framed before treatment. For prefabricated assemblages, consider the feasibility of assembling the structure, then disassembling, treating, and reassembling.

d. Site Requirements. NAVFACENGCOM and Field Divisions have applied biologists on their staffs who should be consulted during the planning, design, and construction stages for information on wood-destroying pests at the specific site.

5. FIRE RETARDANT TREATMENT. Follow recommendations in "Wood Handbook" (U.S. Dept. of Agriculture) and in "Fire Protection Handbook" (National Fire Protection Association). Pressure impregnation is the preferred treatment.

6. CLIMATIC INFLUENCES. Climatic influences for cold and tropic regions are as follows:

a. Cold Region Conditions. For cold region limitations, see NAVFAC DM-9, Cold Regions Engineering. Engineering properties usually are not appreciably affected when wood is subjected to extremely low temperatures.

b. Tropical Conditions. Engineering properties of wood are not appreciably affected in tropical climates. However, rot and insect attacks are aggravated in tropical humid areas, and all timber for permanent construction in tropical areas should be preservative treated, except local native hardwoods as discussed in Section 3, Part 1, para. 2a of this DM. See NAVFAC DM-11, "Tropical Engineering," for details of construction. Structural bonding to other materials should be by means of epoxy resin adhesive. Bonding of wood to wood can be made by a variety of adhesives, such as those covered by Military Specification MIL-A-22397 for marine or severe outdoor use and Federal Specification MMM-A-181 for general purposes.

7. LIMITED LIFE STRUCTURES. The provisions of DM-2.1 shall apply. Additionally, provisions of the Design Standards relating to decreased allowable stresses for full load, permanently applied, shall be disregarded and the use of untreated timbers can be considered for applications normally requiring treated timber.

8. TERMITE CONTROL. See NAVFAC DM-1, "Architecture." Also see Guide Specification TS-02250, "Soil Treatment for Termite Control." Soil should be treated prior to construction.

S. I. Conversion Units

The following metric equivalences were developed in accordance with ASTM E 621 and are listed in the sequence as they appear in the text. All equivalences are approximate.

1/8 inch	=	3 mm
3/8 inch	=	10 mm
18 inches	=	460 mm

REFERENCES

AASHTO Standards. American Association of State Highway and Transportation Officials, Washington, D.C. 20004
Standard Specifications for Highway Bridges

AITC publications. American Institute of Timber Construction, Englewood, Colorado 80110
Timber Construction Manual

APA publications. American Plywood Association, Tacoma, Washington 98401
Plywood Design Specification
Plywood Folded Plates
Plywood Diaphragm Construction

AREA publications. American Railway Engineering Association, Chicago, Illinois 60605
AREA Manual for Railway Engineering

ASTM publications. American Society for Testing and Materials, Philadelphia, Pennsylvania 19103
ASTM E-380. Standard Metric Practice Guide

AWPI publications. American Wood Preservers Institute, Washington, D.C. 20037
Book of Standards

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NAVFAC DM-8	Fire Protection Engineering
NAVFAC DM-9	Cold Regions Engineering
NAVFAC DM-11	Tropical Engineering
NAVFAC DM-25	Waterfront Operational Facilities

NFPA, Handbook of Fire Protection, National Fire Protection Association. Boston, Massachusetts 02110

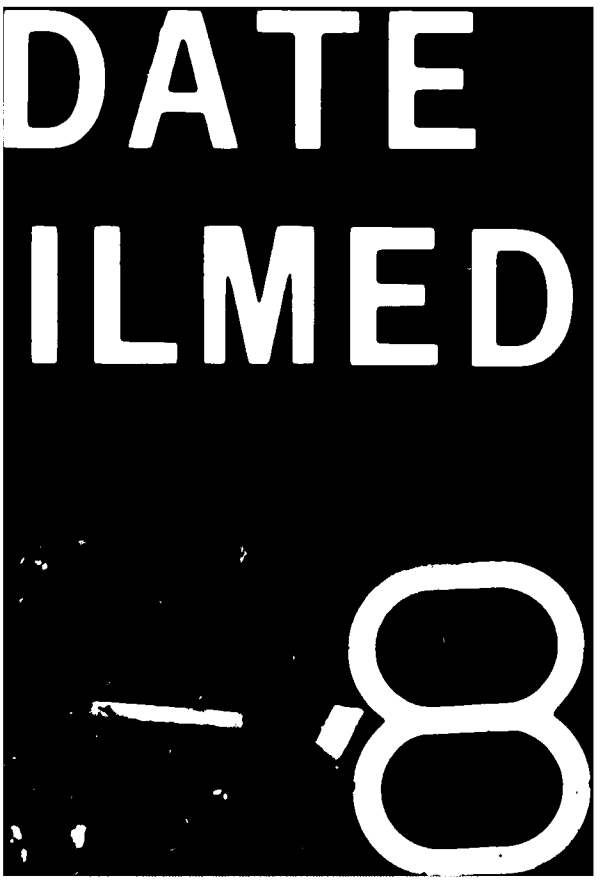
NFPA publications. National Forest Products Association, Washington, D.C. 20036
National Design Specification for Wood Construction

Purdue University Agricultural Experiment Station
Research Bulletin No. 714. Determination of Members Stresses in Wood Trusses with Rigid Joints
Research Bulletin No. 727. Design of Glued Joints for Wood Trusses and Frames

TPI publications. Truss Plate Institute. Hyattsville, Maryland 20783
Design Specifications for Light Metal Plate Connected Wood Trusses

TS Series Guide Specifications. TS-02250 Soil Treatment and Termite Control

USDA publications. U.S. Department of Agriculture, Washington, D.C.
Wood Handbook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